MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

Trimester 1, 2015/2016

EEN7026 – SEMICONDUCTOR PHYSICS AND MATERIALS

2 October 2015
2:30 pm – 5:30 pm
(3 Hours)

INSTRUCTIONS TO STUDENT

1. This Question paper consists of 5 pages including cover page with 4 Questions only.

2. Attempt **ALL** FOUR questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the answer Booklet provided.

Question 1

(a) (i) A silicon sample is doped with phosphorus to $5x10^{16}$ cm^{-3}. What is the equilibrium concentration of holes at 300 K? Where is the Fermi level in the doped crystal relative to that in the intrinsic material? Given that the Boltzmann constant $k_B = 8.62x10^{-5}$ eV and the intrinsic concentration $n_i = 1.5x10^{10}$ cm^{-3}. [4 marks]

(b) Heavy doping in a bulk semiconductor may result in:
(i) ionized impurity-electron interactions,
(ii) electron-electron interactions, and
(iii) electron-hole interactions.
With aid of diagrams, briefly describe how band structures are affected. [6 marks]

(c) (i) In silicon field-effect transistors under normal field, the inversion layer mobility are strongly influenced by a few scattering mechanisms. With aid a diagram, show how the inversion layer mobility is moderated by these scatterimg as well as the environmental condition. [6 marks]

(ii)The electron mobility of silicon as a function of temperature is shown in Figure Q1c). The silicon is doped with $N_d = 1.3x10^{17}$ cm^{-3}. By comparing between the region A and B, what are the dominant scattering mechanisms and the main causes for these scatterings. [4 marks]

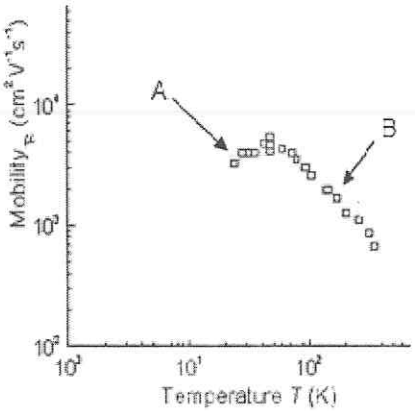

Figure Q1(c)

(d) For steady-state, low-field electron transport, the drift-diffusion equation is given by $J_{nz} = nq\mu_n E_z + qD_z\frac{dn}{dz}$, where J is the current, q the electronic charge, n the electron density, μ_n and D_z are mobility and diffusion coefficient respectively, and z is the z-direction. Comment on the

(i) transport parameters and electron velocity under high field, and
(ii) validity of drift-diffusion equation in mesoscopic regime. [3+2 marks]

Continued--

Question 2

(a) With aids of diagrams, briefly explain
(i)formation of a diamond structure; [2 marks]
(ii)difference between direct and indirect semiconductors. [1 mark]

(b) The point group of diamond structure is given by $\frac{4}{m}\bar{3}\frac{2}{m}$, explain the types of symmetry it has. [3 marks]

(c) (i) By mean of a simple diagram, explain what is a "negative crystal" ? [2 marks]

(ii) Sketch and the label the crystallographic planes of a negative crystal in (100) silicon. What is the common name for this type of microdefect. [2 marks]

(iii) With aid a diagram, briefly explain how a negative crystal is formed from point defects during Czochralski melt-growth of silicon ingot. [4 marks]

(iv) Briefly describe how these negative crystals affect the gate oxide integrity. [3 marks]

(d) (i) Define *surface* of a solid sample. [1 mark]
(ii) Name the surface features as shown in Figure Q2(d). [3 marks]
(iii) Briefly explain the following :
(iii.1)*surface reconstruction* [2 marks]
(iii.2)dimerization [2 marks]

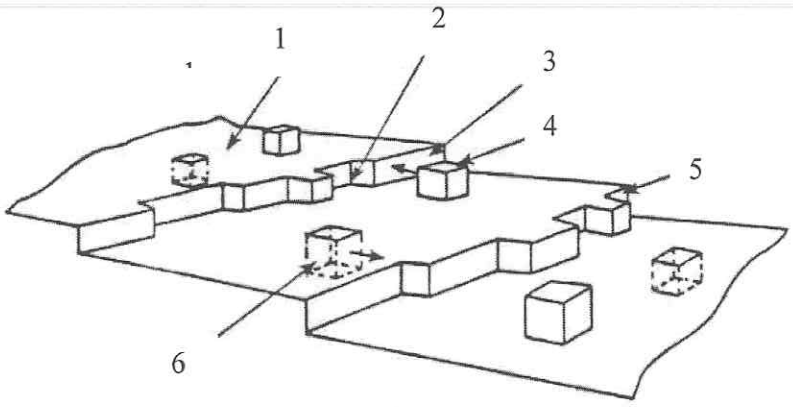

Figure Q2(d)

Continued--

Question 3

(a) Explain the significance of silicon in Wafer/ IC fabrication with the advantage in terms of cost.

[8 marks]

(b) (i) Describe the correlation between crystal growth rate and flow pattern density with reference to Flow Pattern Defect (FPD)

[7 marks]

(ii) Draw the correlation number of defects and the depth in the CZ sample wafer by the two-temperature Laser Scattering Tomography (LST) method.

[3 marks]

(c) Illustrate the mechanism involved in gettering technology in silicon wafers by a diagram.

[4 marks]

(d) List down the processes involved in growth of silicon crystals with ultra-low impurity levels. [3 marks]

Continued--

Question 4

(a) Explain the conversion process from polysilicon rod into a single-crystal by Float Zone (FZ) method.

[6 marks]

(b) Describe the significance of "Strained silicon"

[3 marks]

(c) Illustrate the oxygen profile during the SIMOX process with different implantation doses.

[4 marks]

(d) Describe the basic theory of Vapour Phase Epitaxy with suitable diagram.

[7 marks]

(e) Describe the process involved in growth of single crystal silicon.

[5 marks]

End of Paper